Creeds!" Legally, matters are not yet settled in that respect; but practically, the restrictions hitherto existing have been given up by those in power, on account of the strength with which the Liberal current has set in. All this is a sore grievance to the monkish fraternity; and they seem to have thought that it was time to give the "godless revolutionists," who would do away with all religious persecution, a serious warning. The effect of that outrage at Burgos will, however, be little to the advantage of Ultramontanist reaction. In a political sense, the Spanish Revolution may yet undergo many shocks and counter-shocks, but one thing is certain: that the days are gone by, when Spain, with all its successive Liberal risings, and with all the curbs that had latterly been placed upon the influence of the Roman Catholic clergy, could still be said to be in toleration of other creeds far behind Turkey.

KARL BLIND.

ART. VII.—1. *The First Principles of Observational Seismology.* By R. MALLET. 2 vols. Royal 8vo. London. 1862.

2. *Untersuchungen über das Phänomen der Erdbeben in der Schweiz.* Von G. H. OTTO VOLGER. 3 Theile. Gotha. 1857.

3. *Volcanoes and Earthquakes.* By MM. ZURCHER and MARGOLLÉ. 8vo. Philadelphia and London. 1869.

THE titles placed at the head of this article indicate three as characteristic books as could be selected from among the mass of publications devoted either to earthquakes alone or to earthquakes and volcanoes conjointly. In the last one on the list we have a fair specimen of a class of books which are becoming quite common, which mostly originate in France, are translated in England, and are reprinted here, and which, while pretending to be scientific, are, in reality, as far from having any claim to that character as possible. The principle on which these books are got up seems to be this: A number of showily designed and elegantly engraved wood-cuts are manu-

factured, and then some scientific penny-a-liner is hired to put together a text to match the pictures, no time being allowed for doing the work properly, even if the person selected were competent, — which is rarely the case, — the dominating idea being, evidently, to produce something which a not very critical public shall be tempted into buying, on account of the beauty of its mechanical execution, and with the incidental advantage of getting something scientific into the bargain.

The materials for the illustrations and text of such books are taken right and left without acknowledgment, the one caricatured and the other "popularized," — that is to say, enormously exaggerated or misrepresented, partly through ignorance, but chiefly through a desire to produce a sensational effect. The result is even worse than that produced by the modern sensational novel; for the latter is read, thrown away and forgotten, while the pseudo-scientific and elegantly illustrated volume is carefully laid away in the book-case, and referred to as a standard authority, and most certainly added to the dead weight of every public library, crowding out that which is really valuable in the same department, and which is overlooked, perhaps because it is a little old, because its exterior is not attractive, or because its appearance has not been heralded by a publisher's fanfare.

There could not be a better instance selected, as a text on which to preach a sermon, *à propos* of this style of illustrated works, than that furnished us by this book of MM. Zurcher and Margollé, whoever they may be. The illustrations are showy, and, as far as the engraving is concerned, well executed, though badly printed in the English edition from the purchased electrotypes, while, in the original, that branch of the mechanical execution was undoubtedly carefully attended to. But let any one conversant with the subject of which the volume treats examine the illustrations, and he will see at once that the drawings were made by persons entirely ignorant of what they were attempting to represent. Thus, in the views opposite pages 10 and 34, an attempt is made to show the phenomena of violent eruptions of Etna and Vesuvius. Now, if there is any characteristic feature of these eruptions, it is the

straightness of the column in which the projected material ascends until it reaches its highest point. In these drawings, on the contrary, apparently in order to add the curve of beauty and grace to the picture, the column, in both cases, is made to ascend in an elegantly waving line, as untrue to Nature as possible. Again, every one is familiar with the sketch of Cotopaxi, given by Humboldt, as an illustration of a beautifully regular volcanic cone, and which has figured in hundreds of books for the last fifty years, — notably in our school geographies. Humboldt, in his sketch, misled by the invariable tendency of the eye to exaggerate the slope of mountains, represented the inclination of the sides of the cone as 48°, while the photographs show that in reality this angle is no more than 28° or 29°, the greatest inclination, just at the summit, being only 32°. Now, on the wood-cut in MM. Zurcher and Margollé's book, the slope of all the snow-covered part of the volcano is given as 55°, while the effect of the whole is very much like what one might imagine would be produced by a stove-funnel perched on the summit of a big boulder. This is the character of the illustrations throughout; there is one, however, which surpasses all the others in its ludicrous absurdity, — representing a great number of Calabrian peasants in the act of being swallowed by earthquake chasms, the whole style of the thing being well suited to the pages of a comic almanac, perhaps, but certainly not to those of a scientific work. Of the text of this book it may be said, without hesitation, that it is fit to go with the illustrations. Let a single suggestion be quoted from it, to show how that which is unsound in theory, but at the same time brilliant and peculiarly French, is mixed with something supposed to be popularly and economically interesting, — the idea being to convey the impression that science has its practical as well as its abstruse side. M. Élie de Beaumont, a distinguished French geologist, has devoted much time to tracing out on the earth a regular geometric arrangement, with which he thinks the lines of upheaval of mountain chains may be found to coincide, and which he calls "a pentagonal network." The idea is ingenious, and has been elaborately wrought out by its author, but accepted by few of the leading geologists at the present day. Our authors, however, make both themselves

and the pentagonal network ridiculous, by advising that it should be used as a guide in boring for springs of petroleum. They even trace an imaginary line from Iceland straight to Oil Creek, "places remarkable for their bituminous emanations," as a guide to "oil prospectors." What a pity this brilliant idea had not been suggested before the collapse of the great bubble! One might then have had the "Great Consolidated Pentagonal Network Petroleum Company" to add to the list of other remarkable things in that line. All that is said of the volcanoes and volcanic rocks of our own country in MM. Zurcher and Margollé's book is equally curious, as an exhibition of entire ignorance of our geography and geology. There are just about as many misstatements as there are lines in the two pages devoted to North American volcanoes.

Herr Volger's book is as thoroughly German as that just noticed is French. This author, living at a distance from any region of volcanoes and great earthquakes, but in one where moderate shocks are frequent, and having a strong propensity to look at natural phenomena in what may be called "the small way," has evolved a theory of earthquakes from the depths of his moral consciousness, and then endeavored to bolster it up by collecting great numbers of facts, also of the small kind, entirely ignoring the greater facts, to which his smaller ones are as the ripple on the surface of the ocean in a gentle breeze to the great tidal wave which encircles the whole globe in its motion, and stirs the waters to the very profoundest depths. The book, however, quite different from that of MM. Zurcher and Margollé, is valuable as presenting the extreme views of the school to which the author belongs, and as extremely ingenious in its defence of them, although thoroughly wrong in its fundamental ideas, — as much so as one would be who should endeavor to work out the comparative anatomy of the elephant by a microscopic examination of the pimples on his hide.

Mr. Mallet's book is as different from either of the others as possible. In order to make its character intelligible, it will be necessary to give some idea of his previous publications, and of those of other really scientific investigators in the same line of research, and to show how and when this

branch of geological science acquired a right to the special name it now bears, that of SEISMOLOGY, a term derived directly from the Greek, and signifying the Science of Earthquakes.

The phenomena of volcanic and earthquake action, inseparably connected in the popular mind, and not easily disentangled from each other by the scientific, must necessarily engross a large share of thought in regions where they are frequently manifested, and especially at the time when such manifestations are peculiarly violent or destructive. As no exhibition of the forces of Nature is so sublime as that of the volcano, or so fearful in its consequences as that of the earthquake, it was natural not only that allusions to these phenomena should be found in the oldest writings of all nations inhabiting regions liable to such visitations, but that their very cosmogonies should be profoundly affected by these workings of unseen forces. Hence, in all the sacred writings of the nations inhabiting the vicinity of that cradle of civilization, the Mediterranean, a region liable to earthquakes, and well provided with volcanoes, we find a substratum of belief in occasional conflagrations and deluges by which the gods were wont to arrest the career of human wickedness, and to sweep off from the face of the earth its inhabitants, in order to make way for a new and improved creation. Such ideas pervaded the Egyptian, the Hindoo, the Hebrew, the Arabian, and the Greek mythology; and vestiges of the same are found in the earthquake-shaken regions of South America; while we are not aware that any trace of them can be discovered in the cosmogony of the North American Indians, dwelling in a region but little liable even to slight earthquake shocks, and entirely free from volcanoes.

In consequence of the effect which violent earthquake shocks produce on the material progress of the countries subject to them, and of their direct relations to the welfare of the human race, it is evident that these and kindred events stand in a different relation to history from the ordinary phenomena of geology. Those operations of Nature which proceed slowly and quietly, without destruction of life and property, are not so calculated to excite immediate and universal attention as those which are accompanied by devastating effects over vast

regions. Yet the former class may in reality be of as much importance in modifying the surface of the globe, and may finally bring about results as momentous, as any immediately following great earthquake shocks or volcanic eruptions. Thus, slow upheavals or depressions of large areas of land do really produce changes profoundly affecting the welfare of great numbers of people; but these changes take place so slowly that they are prepared for beforehand, and their effect is spread over very long periods, and is not strikingly perceptible at any one moment. That such changes were occurring in past times is clearly demonstrated, and there is every reason to suppose that they are going on now. Indeed, it is not difficult for the geologist to point to the very regions where slowly, but surely, the ground is sinking over large areas, and where alterations in the distribution of sea and land will in time have accumulated sufficiently to produce materially important results in relation to vegetation, animal life, and the development of the human race.

In view of the above, it may well be supposed that the number of volumes devoted to descriptions of the phenomena of earthquakes and volcanoes, in all languages, is very great. M. Alexis Perrey has given a list of eighteen hundred and thirty-seven works on earthquakes published up to 1856; but he admits that it is not complete. Those relating to volcanoes and volcanic phenomena are undoubtedly more numerous, but no one appears to have set about making a full catalogue of them. On the subject of Vesuvius alone, the list of volumes and scientific papers — many of the latter much more important than some of the separate works — would embrace many hundred titles, perhaps thousands. Most of these works are purely descriptive of the incidents observed, as the number of persons killed, or of buildings thrown down; they do not attempt to philosophize or generalize, or, if they do, it is in a moral or religious strain rather than a scientific one. The descriptions of volcanic phenomena are, on the whole, much more satisfactory than those of earthquakes, as will be easily understood. The former are more at the command of the observer, are longer in duration, and less appalling in their results. Earthquakes, on the other hand, at least those of magnitude,

come unexpectedly, give no indication of their probable violence or duration, and so unfit the mind for calm observation that it is only by previously arranged automatic machinery that we can expect to get accurate information as to those points in regard to which the palpable mementos of their occurrence are not left after the shock has subsided. Hence it is only of late years that earthquake phenomena have begun to be thoroughly investigated, and that the science of Seismology has taken a position among those branches of research in which accuracy of statement is expected.

Since history has preserved more or less complete records of earthquake shocks, in various parts of the world, from very early times, it would naturally be inferred that light might be thrown on some of the obscure points in seismological science by carefully collecting and tabulating all that is scattered through innumerable published volumes, in regard to the time, place, and extent of earthquake phenomena, and that this would be the necessary preparation for any thorough working-up of the subject. That such a working-up was desirable was evident; for, although most geologists, following Humboldt and Buch, were pretty clearly in accord with regard to the general cause of volcanic eruptions and earthquakes, yet much remained to be done to make the *modus operandi* of the internal forces more clear, and especially to furnish material for combating the views of a small class of geologists who persistently refuse to adopt the views formulated by Humboldt, and desire, on the other hand, to refer all these phenomena, as far as possible, to local causes, as will be explained farther on.

The paper read by Humboldt, in 1823, before the Berlin Academy, "On the Structure and Mode of Action of Volcanoes in Different Parts of the Globe," contained the first truly philosophical discussion of this subject; and the ideas with regard to the origin of volcanoes and earthquakes, then first rather vaguely announced, and afterwards more clearly formulated in the "Cosmos" (1845), have been the guiding thread by which most investigators in this branch of science have endeavored to work their way through the labyrinth of difficulties in which they have found themselves involved. The grand gen-

eralization of Humboldt, by which the whole subject of the theory of these phenomena was summed up in a few words in the "Cosmos," is as follows: "In a comprehensive view of Nature's operations, all these [namely, the phenomena of volcanism and earthquake action] may be fused into the one simple idea of *the reaction of the interior of the earth upon its exterior*." Here was simply and concisely enunciated the guiding principle of modern structural geology, and one which, by its subsequent connection with the nebular hypothesis, has become more and more generally recognized as the corner-stone on which the science rests. It is certainly true, that, if this theory be not adopted, there is no central idea in the science, nothing about which it can crystallize, and that the whole assemblage of facts so laboriously collected in physical geology is without anything to compact it into one harmonious whole.

Among those writers who have devoted considerable time to the investigation of earthquake phenomena, besides Humboldt, are: Von Hoff, in whose History of the Changes which have taken Place in the Condition of the Earth's Surface (Gotha, 1822–41) much information is to be found; Friedrich Hoffmann, in a variety of elaborate papers, and especially in his posthumous works, chiefly published between 1831 and 1839; F. C. Kries, whose work on the Causes of Earthquakes was crowned and published by the Dutch Academy in 1820. Peter Merian also made an elaborate investigation of the earthquakes occurring at Basle; Arago published several valuable papers on volcanoes and earthquakes, from 1820 to 1824; and Gay-Lussac contributed an important paper, in 1823, on the theory of volcanoes, in which was the first definite recognition of the vibratory character of earthquake motions. In 1846, Mr. Robert Mallet, of Dublin, published his first paper on the Dynamics of Earthquakes, in the Transactions of the Royal Irish Academy. In 1847, Mr. W. Hopkins furnished his Report on the Theories of Elevation and Earthquakes to the British Association, a paper which has been much quoted and used by various writers on geological subjects. M. Alexis Perrey is, however, undoubtedly the most voluminous writer on earthquakes; his papers and publications are scattered through

a great number of the Journals and Transactions of learned societies, — chiefly those of the French and Belgian Academies, — and bear date from 1841 to 1868; the latest of which we have learned being a statistical account of the earthquakes of Alaska. In the British Association Report for 1858 will be found a list of M. Perrey's publications, from the earliest down to 1858, including fifty-nine titles. His library was recently offered for sale, and was shown by the catalogue to contain four thousand and fifteen works on the two subjects of earthquakes and volcanoes.

Elaborate and valuable as M. Perrey's papers are, especially to those working in this department of science, they are chiefly statistical in their nature, and cannot be compared for scope and general ability with those of Mr. Mallet, the labors of the last-named seismologist being not only those of a compiler, but also of an original experimenter and observer in this field.

Mr. Mallet's results have been laid before the public chiefly in the form of Reports to the British Association, appearing in the volumes for 1850, 1851, 1852, 1853, 1854, and 1858. His principal separate publication is the one cited at the head of this article.

In the Reports of the British Association Mr. Mallet gives a catalogue of all recorded earthquakes from 1606 B. C. to 1842; but for the discussion of the subject in his last Report (1858) he uses the tabular statements of M. Perrey, thus supplementing his own work by that of M. Perrey, for the years 1843–50. All the catalogues up to that time gave, as a basis for induction, more or less precise information in regard to between six and seven thousand earthquakes. It is easy to see, that, the farther we go back in time, the more imperfect the records of earthquakes, as well as of all other physical events, will be found to be. As Mr. Mallet remarks, in speaking of the curves he has drawn, illustrating the frequency of recorded earthquakes during the different centuries: "Our chrono-seismic curve is, in fact, not only a record of earthquakes, but a record of the advance of human enterprise, travel, and observation." Thus, for the years 1700 to 1400 B. C. there are a few scattered facts; then, from 1400 to 900, nearly five hundred years of perfect blank; followed again,

with a few exceptions, by another blank from 800 to 600 B. C. Indeed, the only record of any value for scientific analysis commences about 500 B. C. Since that time, the epochs of the invention of printing and of the Reformation are clearly marked in the expansions of the curves; while the discovery of America, the voyage to India around the Cape of Good Hope, and the vast increase in the commercial intercourse of the world consequent thereon, are also perfectly recognizable in the rapid accumulation of data, and the sudden swelling of the curve of frequency. While only six or seven thousand earthquakes have been tabulated for all time down to 1850, a German author, Dr. K. E. Kluge, was able to obtain records of four thousand six hundred and twenty as occurring between the years 1850 and 1857, inclusive.

We will now endeavor to present, with a few additions of our own, the most important results obtained by the various authors specified, in working over the great mass of statistical information which has been accumulated.

Earthquakes may be considered, *first*, with reference to their geographical distribution, or the position which seismic areas occupy on the earth's surface with reference to each other, to the great features of the earth's surface, and to the position of areas where kindred phenomena — as, for instance, volcanic eruptions — are manifested; *second*, in their relations of time, or with reference to their occurrence, as connected, synchronously or otherwise, with changes of the seasons, or as recurring in cycles, or as influenced by the position of the heavenly bodies, especially the moon or the sun; and, *lastly*, as connected with movements or conditions of the atmosphere, or with electrical and magnetic disturbances.

Let us examine, first, what deductions can be drawn from the geographical position of earthquake areas.

There are several "seismographic maps," showing the geographical distribution of earthquake regions; among these, the best and latest is that accompanying Mallet's Fourth Report to the British Association, and from which the others do not differ much in the general character of the results shown. The first impression produced by looking at any of these should be rather one of alarm; for nearly the whole of the inhabited and

habitable earth appears to be shaded with the various tints implying a greater or less liability to earthquake shocks. It would, indeed, seem, at first sight, as if only those regions were left uncolored in regard to which no information could be obtained. Thus, all of Europe is more or less deeply colored, except a part of Central and Northeastern Russia,—and nearly all of Asia, except the extreme northern portion of Siberia, and the country drained by the Amoor River. On the other hand, almost the whole of Africa and Australia is left blank, as well as the extreme northern portion of North America, and all of South America east of the eastern base of the Andes and south of a narrow belt extending around from New Granada to French Guiana. It is evident that portions of the areas thus omitted in the distribution of the earthquake tint must have been left blank on account of the absence of information in regard to their seismic character. Indeed, it might be asked whether there is any part of the world where earthquakes do not occur. To this question it would probably be safe to reply, that there is no region thickly inhabited by a civilized people, and where consequently there is a pretty complete record of what has happened for a considerable period back, in which there are not occasional slight manifestations of seismic energy. But it is pretty certain, on the other hand, that regions so well known as Brazil, or as some portions of the coast of Africa, could not be much troubled by earthquakes without some information having been gathered in regard to them by the many travellers who have visited those countries. The fact that any area is left uncolored in Mr. Mallet's map is a strong reason for believing that it is probably not liable to severe shocks. Leaving Africa and Australia out of the question, as too little known to allow of positive statements being made concerning them, it may be said that there is hardly any portion of the habitable globe which is not occasionally shaken, but that Eastern South America comes nearest to a desirable state of security in this respect. Most of British North America is also very firm in its position as an integral part of the crust, but is not likely ever to be very thickly inhabited.

On close examination of Mr. Mallet's map, we see upon it

three tints of color, intended to distinguish, as we learn from the accompanying report, the relative intensity of the shocks occurring in the regions designated by them. The deepest tint indicates great earthquakes; the middle tint, those of mean intensity; the lightest color, minor shocks. By "great earthquakes" are meant those in which, over large areas, numerous cities or towns are overthrown, persons killed, rocky masses dislocated, etc.; under the head of earthquakes of mean intensity are included such as were felt over a wide area, but which were not severe enough to have a very destructive effect, and were not attended with much loss of life. The third class embraces those slight tremors of the surface which do not produce any serious destruction or commotion, and which leave but few, if any, traces of their occurrence.

It will of course be impossible, in these pages, to enter into any minute discussion of the distribution of the different bands of seismic energy; but some general idea of their geographical range can be given. Let us examine, first, the position of the patches of deepest tint, — those indicating the occurrence of "great earthquakes." We see at once that the area thus colored is, to a very large extent, coincident with that of the greatest displays of active volcanic forces. As the whole Pacific coast of America and the islands of the coast of Asia are the scene of volcanic phenomena on the grandest scale, so, too, the darkest tint of color follows the coast of the Pacific Ocean around, indicating great earthquakes along nearly the whole line; and when this is not the case, then the color representing the prevalence of shocks of the second order of intensity is given. The great circle of fire about Borneo as a centre, extending from Manila around to Sumatra, exhibits a broad belt of the deepest tint. The same is true of the region connecting the Andes with the Lesser Antilles. Iceland, the Azores, the Canaries, the Cape Verdes, parts of Italy, the country between the Mediterranean and the Caspian, — these are all regions of great earthquakes, and also, as we well know, of great volcanic eruptions. Of regions liable to great earthquakes and not volcanic, the following may be cited as the principal: portions of the coast of China, the region about the mouth of the Ganges, and that south of the mouth of the Indus, the Pyre-

nees, and the coast of Portugal between Lisbon and Oporto. If we should (as we very properly might) distinguish in the region of great earthquakes two divisions, — one in which highly destructive shocks may be expected to occur frequently, and the other where they take place only at long intervals, — we should then find that the former, that is to say, the pre-eminent earthquake areas of the world, are strictly limited to regions of volcanic activity, or to parts of the earth where such activity has only died out in the most recent geological periods. To say also that these regions of great earthquake shocks are almost exclusively in the neighborhood of the ocean is, then, almost unnecessary; since we know very well that there are almost no active volcanoes in existence except near the sea, — those reported in the Chinese annals as occurring in the Thian-Shan range, north of the Gobi Desert, being the only exceptions, while with regard to these there is much uncertainty. The two most prominent facts, then, in respect to regions liable to great earthquakes are, that they are almost entirely coincident with areas of active volcanoes, and that they also lie near the borders of the ocean.

Taking next into consideration the areas of earthquake shocks of moderate intensity, we find that they also (since the greater includes the less) are near coast-lines and volcanic centres, either those now active or else such as have become recently extinct, and especially that broad bands of the tint peculiar to this class are found along many of the great ranges of mountains which are not volcanic, notably at the base of the Himalayas, the Alps, and the Pyrenees, — also on the northern edge of the plateau of High Asia, through the belt of islands off the east coast of Australia, from New Guinea around to New Zealand, and in the extinct volcanic islands of the Atlantic Ocean, — as Ascension, St. Helena, Tristan d'Acunha, etc.

Here, before going any farther, it will be well to speak of the very inaccurate ideas apt to be given by earthquake catalogues of the real number and severity of shocks, and from a very natural cause. In the regions where earthquakes are of rare occurrence, and never severe, the slightest vibration is a matter of great interest, much talked about, and of course greatly exaggerated; especially are the newspaper accounts likely to

represent such uncommon events in the liveliest colors. In a really earthquake-shaken region, like the west coast of South America, and where at the same time newspapers are almost unknown, by far the greater number of shocks are never put on record, or at least they have not been until since the establishment of public scientific observatories, and of these there are but very few, — while in thickly settled and highly civilized regions each slightest jar of the ground has been recorded. This leads to curious results in the records, and might cause very erroneous conclusions to be drawn in regard to the real earthquake character of different regions. Thus it appears, *by the catalogues*, that nearly as many earthquakes have taken place in Great Britain during the nineteenth century as in Chile, — while we know that in the first-named country no very destructive shock has ever taken place, and that even minor ones are very rare. In Chile, on the contrary, several very frightful earthquakes have occurred during the present century; one hundred and twenty-seven shocks were felt at Santiago in thirty-five months, and prudent people decline ever to sleep in a room with the door shut, lest it may become jammed by an earthquake, and egress be rendered impossible. It is a sufficient proof that a region is comparatively safe from real danger, to read as follows: "Newport, R. I., 1766, August 25. Violent shock. *No damage done.*" A violent shock not producing any damage would be a desideratum on the South American coast, where probably the record would have stood: "*A very slight vibration.* No damage done."

It is from considerations like those just suggested, and also, in some degree, through the absence of reliable data, and the habit which our newspapers have of exaggerating all events, whether physical or political, that we may account for the seismological character of our own country being very much misrepresented on Mr. Mallet's map. On it we find the whole region east of the meridian of 95°, excepting a small area about the Upper Great Lakes, colored of the middle tint, indicating a region of considerable earthquake activity. This band is also extended up to the head of the Missouri River, over a belt of country two hundred miles wide.

On the Pacific coast, on the other hand, a broad band of the lightest tint, indicating only an occasional visitation of the lightest possible shocks, extends back from the ocean as far as Salt Lake, including the region north and south between the mouth of the Colorado and the northern line of California. This tint is also continued up the coast to the Aleutian Islands, excepting only a small area about the mouth of the Columbia River, where two active volcanoes are inserted, and, apparently in consequence of their presence, the region thereabout is colored of the middle tint.

Now certainly our personal experience — and this is well supported by the catalogues — shows that we live in a region where earthquakes are very little to be apprehended, and where there is no record of any destructive one ever having taken place. We have no remembrance of ever experiencing a shock, even of the slightest kind, in Massachusetts. We have to go back as far as 1755 to find any record of a decided earthquake, and this seems to have been connected with a great agitation extending over a large part of the earth's surface, and it is not unlikely that the focus of disturbance was far out at sea. It will be remembered that the "Great Lisbon Earthquake" commenced November 1, 1755, and that it was one of the most violent and widely extended on record. The shocks continued, at various places around the Mediterranean, with occasional intervals, for many months, and nearly the whole circumference of the Atlantic Ocean was in a disturbed condition, while portions of the East India Islands were also vibrating synchronously, if not sympathetically, with the other side of the globe.

The shock of November 18, 1755, was felt all along the Atlantic coast, between Halifax and Maryland, and west certainly as far as Lake George, in New York. It was quite severe at Boston, — more so, probably, than anywhere else within our territory. This earthquake was described by Professor Winthrop, of Harvard College, in the Philosophical Transactions of the Royal Society (Vol. L. Part I. p. 1), with considerable detail, and with no little skill and critical acumen. The shock was violent enough to throw down a considerable number of chimneys and the gable ends of some

brick buildings. Throughout the State many stone fences were more or less injured. Some cracks were made in the ground near Scituate, from which water and sand issued, to the extent of "many cart-loads." Previously to that, in 1638, 1658, 1662, and 1727, shocks had been felt in Boston, of which that of 1662 was severe enough to throw down some chimneys. It does not appear, however, that any person has ever been killed by any earthquake in New England; so that it is pretty safe to conclude that some, if not all, of the chimneys thrown down had been built with very poor mortar. We are not aware that there is any record of any considerable shock having taken place in New England since that of 1755.

On the Pacific coast of the United States, however, hardly a year elapses without some pretty severe shock. The number of earthquakes recorded in California for the thirteen years ending December, 1863, is one hundred and eleven. Many very heavy ones have occurred there since the beginning of the present century. In 1812 the whole southern part of that State was violently agitated during four and a half months. In some regions the inhabitants abandoned their houses altogether. Several of the "Missions" — substantial stone buildings — were thrown down; in one — that of San Luis Capistrano — religious services were going on at the time, and many of those present were killed, the number of persons thus perishing being stated by various authorities at from thirty to forty-five. A number of lives were also lost at the Missions of La Purissima, one hundred and twenty miles distant from that of San Luis Capistrano. It must be recollected that the State, then the Mexican province of Upper California, was at that time extremely thinly inhabited. Had it been a populous region, it would seem, from the descriptions of the character of the shocks, that the loss of life and property must have been very great. Among the earthquakes which have happened in California since it became a part of our own territory, two are particularly to be remembered, — those of October 8, 1865, and of October 21, 1868. The first did considerable damage to property in San Francisco, and the other was severely felt over an extensive area, demolishing a great number of buildings in that

city, and especially in the towns on the opposite side of the bay between Oakland and San José. Several persons were killed by falling fragments. In view of the above-cited facts, it will readily be seen that even coloring both sides of the United States as equally liable to seismic demonstrations would not at all be supported by the facts; while representing the Atlantic coast as more shaky than the Pacific slope is very far out of the way.

The extending of a band of color indicating serious earthquake action up the Valley of the Missouri is also quite unsupported by the facts. It is true, however, that a region of a few hundred square miles in area, near the junction of the Mississippi and the Missouri Rivers, was subjected to violent earthquake shocks during several months, in the years 1811–12,—a remarkably exceptional case in every respect, and therefore worthy of a brief notice. This disturbance commenced December 16, 1811, with an earthquake which was felt over a large portion of the Valleys of the Mississippi, the Ohio, and the Arkansas; it was also noticed as far to the southeast as Florida, although the shocks were feeble to the east of the Alleghanies. New Madrid, on the Mississippi, in latitude 37° 45′, a little below the mouth of the Ohio, seemed to be the focus of the disturbance, and the shocks continued there daily and almost hourly for several months; they are reported as having finally ceased about the time of the great earthquake of Caracas, March 26, 1812. As a result of this, a large tract of country west of New Madrid, extending seventy or eighty miles north and south, and thirty east and west, was permanently sunk considerably below its former level, and converted into a marsh. This was truly an interesting and peculiar occurrence, as it is almost the only instance on record of a region far from volcanoes, from mountain chains, and from the ocean, being subjected to a long and violent disturbance of this kind; it is also remarkable that the heavy shocks in this locality have been repeated only once, so far as we are able to learn,—namely; in 1865, August 17, when a considerable part of the Mississippi Valley was shaken with some violence, although no serious damage was done at any point. The shock was most distinctly felt at New Madrid. It is said that light vibrations

have frequently occurred in the district of the "Sunk Country," as it is called, since the great ones of 1811–12.

An examination of the catalogues and maps of earthquake areas, with a view to their correlation with the geological structure of those areas, shows some very interesting facts. It is clear that persons living on the older geological formations have much less reason to apprehend earthquake disturbances than those who have under them the more recent members of the series. There is hardly any region liable to severe shocks where there are not, in the vicinity at least, large accumulations of strata belonging to one of the later geological epochs. Chains of mountains made up of Palæozoic rocks, as, for instance, the Urals, the Appalachians, the Brazilian ranges, the Scandinavian mountains, and the Laurentian mountains, are never the scene of violent or destructive shocks.

Where the newer formations do exist, but where, however, they remain undisturbed, or nearly in the same relative position in which they were deposited, there, too, is immunity from earthquake damage, and, *a fortiori*, where the older formations occur and are entirely undisturbed. Thus, the whole vast region of the Central and Northern-Central portions of North America, north of the parallel 40°, is remarkably free from earthquakes, and we have there one of the largest areas in the world of nearly horizontally stratified Palæozoic rocks. From the western base of the Appalachian chain, towards the northwest, over a wide belt, including the Upper Great Lakes, and trending off towards the Arctic Ocean, there extends a tract embracing many hundred thousand square miles, and included between the eastern base of the Cordilleras and Hudson's Bay, over which only the oldest geological formations occur, and where these have remained almost wholly undisturbed since their original deposition. This is a region left entirely uncolored in the seismological maps, and which, so far as can be learned, is indeed almost, if not quite, exempt from even the minor earthquake shocks. So, too, the region of the Plains in our own territory, although underlaid by the more recent formations, is little, if at all, troubled by earthquakes, and we know that the formations are here also almost horizontal. The same conditions may be traced all over the world, so far as our

information goes; so that we are justified in asserting that it is extremely rare to find earthquakes occurring over geologically undisturbed areas, or regions where the strata have not been turned up and folded, and that the same is true even where such geological disturbances have taken place, provided they have not been continued down to a recent geological period.

Thus we have shown, that, from a geographical point of view, great earthquakes, and even those of minor consequence, are clearly connected in their place of occurrence with the position of the oceanic basins, with the existence of great mountain chains, and consequently with the distribution of volcanoes; also, that they are unmistakably associated with the existence of the more recent geological formations, and with their most disturbed condition. Hence we have the strongest reasons for believing that earthquake phenomena are dependent on general laws, such laws as have governed the building up of continents and the bringing of the great features of the earth into their present stage of development. They cannot be mere local phenomena, occurring without any mutual relations to each other, or as disconnected with the whole series of geological events which scientific investigations show so clearly to have been governed by a law of progress. The same conclusion may be drawn from a consideration of the extent over which many earthquake shocks are felt, — the magnitude of the area shaken, and its proportion to the whole surface of the earth, being considered, very fairly as it would seem, a decided indication of the magnitude of the cause. One of the greatest earthquake shocks on record is that already referred to as "the Great Lisbon Earthquake," the centre of disturbance having been situated near the coast of Portugal, and the effects of the shock having been most fearful at that city. This earthquake produced sensible effects over an area of the earth's surface included between Morocco on the south and Iceland on the north, Töplitz in Bohemia on the east, and the West India Islands on the west. The great earthquake of August 13, 1868, of which, however, only the most unsatisfactory accounts have yet reached us, appears to have been felt along the Andes, over a breadth of forty degrees of latitude, and its effects were dis-

tinctly visible in the great waves it raised at Juan Fernandez, on all the Hawaiian Islands, on the coast of Japan, and even in Australia and New Zealand.

On examining the phenomena of earthquakes with reference to the time of their occurrence, various interesting results have been obtained, as respects their frequency, both at different seasons of the year, and while the earth is in certain positions with regard to the sun and moon. It appears, also, that there are certain periods during which the earth is in a peculiarly disturbed condition, and that not unfrequently a large number of shocks take place at about the same time in regions far removed from each other. As a marked instance of this, may be mentioned the latter part of November, 1852, when a large portion of the Pacific coast, both of North and South America, was in motion, at the same time with the whole of the East Indian Archipelago and various intermediate places. This earthquake period commenced in the East Indies, in Southern Sumatra, on the 11th of November, and the shocks continued in various parts of the Archipelago until the 26th, when the great one took place which was felt all over the East India Islands, from Manila to Sumatra. The disturbance was kept up through the whole of December, and, on the 21st of that month, had, in the island of Java, reached a degree of violence exceeding anything previously known. From the 27th to the 30th of November the earth was in constant motion in all the East India Islands. During exactly these days, — that is, from the 26th to the 29th of November, — tremendous shocks were constantly felt in the Great Antilles. On the 26th of November, very severe earthquakes agitated the Pacific coast of North America, from Mexico to Northern California, and indeed the whole region between the Colorado River and the coast was in a state of continual vibration for nearly two months. On the same day, November 26th, an earthquake was felt in Italy; the next day, a slight shock on the Atlantic coast of the United States, and a heavy one on the South American coast; and still the next, another in Chile. It would appear that at this time both sides of the Pacific Ocean, from China to Australia on the west, and between California and Chile on the east, were vibrating synchronously and extensively, and that this condition of

things lasted for nearly two months, while several points in other regions were also seriously implicated in the disturbance. This was undoubtedly one of the grandest epochs of earthquake disturbance which have ever been known, and it is hardly possible to explain the synchronous occurrence of so long-continued and violent a series of shocks in the regions affected by simply considering it as an accidental coincidence. A great many other instances might be cited of earthquake disturbances taking place at the same time, in regions far distant from each other; while, on the other hand, it is true that severe shocks have often taken place which were limited to quite a narrow area.

The coincidences of earthquakes and volcanic activity are curious, and not easily brought into harmony with any theory. The great fact is clear enough, that by far the most severe and the most frequent earthquake shocks are in countries of volcanic activity. But it is also not to be denied that volcanic eruptions do occur occasionally in perfect quiet, so far as vibrations of the adjacent crust are concerned. The same uncertainty exists with regard to the internal connections and sympathy of volcanic vents, whether at a distance from or near to each other. Cases have repeatedly occurred where adjacent volcanoes have not sympathized in the slightest degree in their periods of rest and activity, even when in immediate proximity to each other. One of the most curious of these instances is that of the summit crater of Mauna Loa, and Kilauea, the famous side-crater on the same mountain, nearly ten thousand feet lower down. It has repeatedly happened that the upper one has been in violent eruption, while the lower was in no degree more active than usual, thus showing that the two great vents of the same volcano were not in immediate connection. On the other hand, it has often occurred, that, of two volcanoes near each other, or even at a considerable distance apart, one has become absolutely quiet at the very moment when the other has suddenly burst into eruption; the instances of this kind are, some of them, so marked, and the correspondences in the commencement or termination of the seasons of activity have been so exact, that it would be quite impossible to pass them over as mere accidental coincidences.

The question has been much discussed, whether volcanoes in reference to earthquakes act as "safety-valves," — that is, whether their eruptions, once commenced, can be looked upon as in any degree removing the probability of violent shocks. That such is the case is the almost universal belief through earthquake-shaken regions in the neighborhood of great volcanoes. Indeed, it seems not unreasonable to suppose, that, the internal forces having once found vent for their energy in the eruptive action, the vibration of the crust, which can hardly be looked on as anything else than the result of the struggles between expansive force on the one hand and the pressure and tenacity of the superincumbent material on the other, would be suspended. On examining the records, it will be found that there are many instances which show clearly that earthquake shocks, previously severe, have ceased entirely at the moment of the eruption of some adjacent volcano ; while there are other instances in which severe earthquakes have been felt some time after great eruptions in the vicinity had commenced. In the very numerous instances where volcanic eruptions have been the signal for the stoppage of a long series of earthquake shocks in the vicinity, it is difficult to admit any other explanation than that the issuing of the lava has relieved the pressure and thus removed the cause of the shocks ; while in the cases of an opposite character, where the vibration still continued after the eruption had begun, it is reasonable to suppose that the relief was only local, and not sufficient to affect the whole adjacent region.

As before remarked, the curves indicating the number of recorded earthquakes in all parts of the world expand rápidly as we approach the present epoch. There is no reason to suppose, however, that this means anything more than that our records are growing every year more complete : only the observations of the last century and a half can be considered as making the slightest claim to completeness. No inference can be drawn at present, then, or probably for a long time to come, as to whether seismic energy, as a whole, throughout the world, is on the increase or decrease. On this point we shall be for a long time in the dark. But the question next arises, whether the records, especially those of the last two or three centuries,

exhibit, when plotted in curves, any indication of irregular or paroxysmal energy; that is, whether there are certain epochs during each century, when the number and intensity of shocks are greater than at others. Although the dates are far too incomplete to admit of a perfectly satisfactory answer to this question, Mr. Mallet thinks he is justified in asserting that there are minor intervals of comparative repose, averaging from five to ten years in duration, alternating with periods of considerably increased activity of a year or two in length. These shorter intervals do not seem to follow any regular law, so far as can be made out from the curves; but they seem to be in connection with periods of fewer earthquakes, and usually with the occurrence of less violent shocks. There are also two very well marked epochs of extreme violence and frequency of earthquakes, — one towards the end, and one, still more violent than the other, about the middle of each century. The form of the curves seems to indicate a comparatively sudden burst of seismic energy at each great paroxysm, and then a more gradual subsidence of the action; as if the disturbing forces had been of a nature to reach rapidly the maximum of their power, and then to sink more slowly into their normal condition of activity. Still, the data are few for general results of much weight in regard to long periods of alternate repose and paroxysmal energy. If, as Mr. Mallet thinks, such conclusions can already be drawn, it is a strong argument in favor of considering earthquake action to be connected with some great general cause, commensurate, in the magnitude of the area in which it acts, with that of the earth itself.

In comparing the relation of earthquakes to the times of the year in which shocks have occurred, in order to ascertain whether there are months or seasons in which seismic energy is more developed than in others, quite interesting coincident results have been obtained by all who have occupied themselves with these investigations. In the first place, it is clearly made out that there are more earthquakes, in the northern hemisphere, during winter than summer. Thus, Dr. Kluge gives, for the shocks registered from 1850 to 1857, nineteen hundred and eighty-four as occurring in the winter half of the year (September to March), and only eighteen hundred

and thirty-four as taking place in the summer half. The months in which the smallest number of shocks took place were May, June, and July; and October, December, and February, those in which the number was greatest. Mr. Mallet draws substantially the same results from the comparison of the curves of mensual seismic energy for the whole period of the catalogue, or thirty-two centuries. In the northern hemisphere he finds the annual paroxysmal minimum to occur in July, and the maximum in January, while the preponderance of winter over summer in the number of shocks is very decided. The results of observation in the southern hemisphere agree with those in the northern, the frequency of earthquakes there being greater in summer (our winter) than in winter (our summer); but the observations are so limited in number, and the area is so much more extensively covered by water, that at present any deductions of this kind in regard to the southern hemisphere have much less weight than the similar ones for the northern. The same results are shown when the months are grouped into four seasons, — the curves showing clearly a maximum for the three winter months, and a minimum for the summer.

Another coincidence appears to have been pretty clearly indicated, if not positively made out, by the labors of Messrs. Mallet and Perrey: namely, the occurrence of a maximum of earthquake shocks about the time of the winter solstice, and a minimum at the autumnal equinox. And there is still another branch of inquiry with reference to the frequency and violence of earthquakes, which is of great interest, although as yet by no means thoroughly worked out: that is, the action of the moon on the earth, or the connection between the phases of the moon and the recurrence of shocks. The coincidence of certain great earthquakes with extreme high or low tide had been repeatedly noticed in South America many years ago, and the probable influence of the moon on the interior of the earth asserted by different scientific authorities. Baglivi, an Italian author, in his description of the Roman earthquake of 1703, published in 1737, notices particularly the fact of the more common occurrence of earthquakes at the time of full moon. M. Perrey was the first, however, to enter into the labo-

rious calculations necessary to throw further light on this question of so much interest; and although it cannot be considered as thoroughly settled, still the facts seem to indicate that the action of the moon, or of the sun and moon combined, is really perceptible in increasing the number and violence of earthquakes at certain periods. M. Perrey's results, as obtained from a combination of the observations of 1844 – 47, are as follows: *First*, that earthquakes occur more frequently at the Syzygies than at the Quadratures; *secondly*, that they also are more numerous at the Perigees than at the Apogees; and, *finally*, that, whenever a disturbance is going on, the frequency of the shocks is increased by the passage of the moon over the meridian of the place in question. These results would indicate that the moon has an action on the interior of the earth somewhat analogous to that which it exerts on the ocean, — the time of greatest frequency of shocks agreeing with that of the highest and lowest tides. The great interest of this investigation will be easily understood, since it bears very directly on one of the most vexed questions of modern geological science, namely, whether the interior of the earth is really in a liquid state, or sufficiently so to admit of its yielding to the attraction of the sun and moon in such a degree as to produce a sensible result, as would be the case, provided it could be clearly proved that the supposed lunar influence on the frequency of earthquakes really existed. Such an investigation, moreover, has an important bearing on many points of theoretical geology, and it will certainly not be dropped until the question has been definitely settled. Of M. Perrey's conclusions Mr. Mallet says, that they rest upon so narrow a basis of induction that they must be accepted with caution; yet he admits that they possess more than sufficient probability, from physical considerations, to induce further inquiry. The Committee of the French Academy of Sciences to which M. Perrey's conclusions were referred were evidently much impressed with the character of his results, although cautious in accepting them, until they should be confirmed by the reduction of future observations, or by going back and computing a still greater number of older ones.

However important the relative frequency of earthquakes, as

compared with the positions of the sun and moon, may be to the scientific man, as having a profound theoretical significance, people generally are much more interested in the connection of seismic with meteorological phenomena. A great many persons think that they remember some peculiarities of the weather as having preceded any great shock; and in almost every earthquake-shaken region there are popular theories as to the premonitory symptoms of these disturbances,—although these are very different in different places. The most common one is, perhaps, that oppressive heat, accompanied by unusual stillness of the atmosphere and a light mist, is a sure forerunner of a shock. In accordance with this theory, the inhabitants of San Francisco were greatly excited, last September, by the occurrence of a remarkably smoky appearance in the atmosphere during several days; and a report having been set afloat that an uncommonly high tidal wave had been experienced in the harbor, the city became wild with excitement. Nothing unusual happened, however, and the smoke was afterwards traced to burning forests far north on the coast. The most careful comparison of the catalogues of earthquake occurrences with registers of the weather has failed to reveal any substantial reason for supposing that any of these peculiar indications really do precede the shocks. Only this much appears probable: that a great depression of the barometer, implying a diminution of the pressure of the atmosphere on the earth, may be in some cases the determining cause of an earthquake. This, as we can easily conceive, might be the case; since, if we suppose the normal condition of the crust of the earth in an habitually disturbed region to be that of a nicely balanced equilibrium between the internal forces seeking exit, or relief by change of place, and the pressure of the overlying material, gravity and tenacity acting against expansion, it is not unreasonable to admit that a sudden depression of the barometer, perhaps to the amount of two and a half inches, equal to one twelfth the whole weight of the atmosphere, may turn the scale, so that the crust shall give way and the pent-up forces find relief, giving us the evidence of it in a vibration of the superincumbent strata. There are many facts which seem to indicate that the severe storms, gales of wind, and heavy

rains, which have repeatedly been observed to occur simultaneously with earthquake shocks, and which, from meteorological causes, are preceded by a remarkable fall of the barometer, are thus causally connected with seismic disturbances. The depression of the mercurial column indicates a change in the currents of the atmosphere, which will result in a violent storm, and the diminished pressure of the atmosphere is the direct agent in starting the vibration, which takes place sooner than it would have happened, had it not been for this disturbing element.

Many curious statements have been made with regard to the presentiments of approaching earthquakes manifested by different animals, some of which seem well authenticated, while others must be set down as the results of excited imaginations. Some of the peculiar actions ascribed to animals may easily be accounted for by the emission of carbonic acid or other gases from the ground, which is known to accompany some earthquakes in volcanic regions, and which might be perceptible to animals whose sense of smell or nervous susceptibility was more delicate than our own. Dogs are supposed to be peculiarly sensitive in this respect, and hogs and geese are believed to show fear of approaching volcanic disturbances sooner than other animals. Birds generally are very quick at taking alarm, as might naturally be expected from their delicate organization. All incidents recorded with regard to the behavior of animals, before and during earthquake shocks, must be taken with many grains of allowance; but such as are well authenticated are extremely interesting, as indicating differences between the nervous susceptibilities of man and the lower animals.

Whether there is any relation between earthquake phenomena and the magnetism of the earth is a question which has been frequently discussed, and for the satisfactory answering of which the data are not yet sufficient. We know no reason why there should be any real connection between the disturbances of the earth's crust and the magnetic currents which circle around it, nor has any been proved. On the contrary, most, if not all, of the investigators in this branch consider that there is no reason to believe that the unusual vibrations

of the magnetic instruments, which have been sometimes observed in earthquakes, are anything more than the mechanical result of the motions of the earth's crust.

We have now gone rapidly over most of the ground which has been occupied by compilers of earthquake catalogues, and given a sketch of the principal results. It must be remembered, however, that a large portion of the data used are entirely wanting in the elements of scientific accuracy, and that in consequence of this looseness of statement only conclusions of the most general character could be drawn from them. So impressed was Mr. Mallet with this fact, that he thus expressed himself at the end of the Report to the British Association which had occupied him for so many years. He says: "In conclusion, I would repeat my conviction that a farther expenditure of labor in earthquake catalogues, of the character hitherto compiled, and alone possible from the data to have been compiled, is now a waste of scientific time and labor. The main work presented for seismologists in the immediate future must consist in good observations, with seismometers advantageously placed at sufficiently distant stations, and galvanically connected as to time, — and in the careful observation of the traces left by great shocks (when of recent occurrence) upon buildings, and other objects, artificial and natural, with a view to determining the nature of the forces that have affected them, aided by the resources of the physicist and the mathematician."

Just about the time the above-quoted conclusions of Mr. Mallet were put upon paper, there occurred the great earthquake of December, 1857, which shook a large part of the Neapolitan territory, and was the third in extent and severity of all those of which there is any record as having occurred in Europe, — since more than ten thousand persons were killed by it, and a great number of towns and villages were almost destroyed. Immediately after this calamity, Mr. Mallet applied to the Royal Society of London for a small grant of money, to pay a part of the expense of visiting the locality, and making a thorough investigation of all the facts in the light of the most recent seismological inquiries. The request was acceded to, and

Mr. Mallet travelled carefully over the shaken region during several months, and was afterwards employed for nearly two years in preparing his report, the title of which stands at the head of this article. This report was published in 1862, the Royal Society contributing three hundred pounds towards the expense. It fills two royal octavo volumes, and is most elaborately and beautifully illustrated, in a manner worthy of the first really thorough investigation in the department of Seismology.

It is hardly necessary to state that one investigation has not exhausted the subject; it has rather set the example of what ought to be done for many earthquakes; and it is especially of value, as leading the way in a new line of research, and as showing what can and must be done in order to arrive at as complete a knowledge as possible of the workings of the mysterious agencies by which these great convulsions are brought about. Some of the more important results obtained by Mr. Mallet in regard to the Neapolitan earthquake may here be given, as a specimen of the kind of material which will have to be accumulated from all quarters of the globe before the demands of scientific accuracy shall have been satisfied.

In the first place, in the map accompanying the report in question, the regions in which the shock was equally intense are designated by curves, called *isoseismal curves;* then the whole of the wave-paths, or lines of direction in which the shocks were propagated at each locality, are marked by red lines. These wave-paths of course radiate from the focal point of the shock, and so carefully were they determined, chiefly by observations of the position of fallen buildings, and the character of the movements and fractures in those left standing, that sixteen of these lines, when protracted back, pass through the same focal point, or within a circle of five hundred yards radius around it, while thirty-two more fall within a circle concentric with the former and of one mile radius. Now, theoretically, the intersection of any two wave-paths is sufficient to fix the position of the "seismic vertical," or the point on the earth's surface vertically above the spot where the impulse or shock originated. The evidence, then, in this case was ample for determining this point as accurately as possible; since, what-

ever be the nature of the impulsive force, or however it may operate, the wave of impulse, as propagated outwardly, passes simultaneously, or almost so, from points about the actual focus at a considerable distance from each other, — the point from which the disturbance starts not being, by any means, a mathematical one. The position of the point on the surface vertically over the seismic focus was found, as above, to be near Caggiano, a village sixty miles a little south of east from Naples.

The next important question to be settled was the depth of this focus below the surface, — a point of great interest, as will be perceived at once, in its connection with the theory of earthquake action. This depth can easily be obtained by mathematical calculation, when the distance on the surface from any station to the seismic vertical is known, together with the angle of emergence of the wave-path, the seismic vertical being another wave-path, and the point of convergence of the two being the focus from which the wave started. Of course the limits of error are considerable in an investigation of this kind; but the results, as graphically exhibited on Mr. Mallet's diagram, are quite as satisfactory in their agreement as could be expected. Out of twenty-six separate wave-paths, twenty-three start from the seismic vertical at a depth of above $7\frac{1}{8}$ miles; the maximum depth is $8\frac{1}{8}$ miles, and the minimum $2\frac{3}{4}$ miles.* Eighteen of the wave-paths start from the seismic vertical within a vertical range of twelve thousand feet, and having a mean focal depth of $5\frac{3}{4}$ miles, which may be taken as the depth of the focus. Here is an extremely important numerical result, and similar results from other regions are highly desirable for comparison with this.

It will be impossible here to enter into the detail of the other numerical results obtained by Mr. Mallet, — the position and depth of the focal centre being, of course, the most important, and having been determined in this instance for the first time with any approach to accuracy. Other interesting points discussed in the summing up of the results of the investigation are: the form of the isoseismal areas, — that is, of the regions over which the shock was felt with equal inten-

* These results are given in geographical miles, of sixty to a degree.

sity; the relations of this area to the focal depth; the effects of the physical configuration of the surface and the geological structure of the region on the progress of the wave; the proofs of reflection and refraction of the shock by a range of mountains standing in the way, including reasons why certain areas escaped entirely; the form, position, and dimensions of the focal cavity; the amplitude and velocity of the wave, both on the surface and in the wave-paths; the velocity with which the shock started, and its gradual dying out; the relation of the seismic foci of the Italian Peninsula, and the general relations of the seismic bands of the Mediterranean basin. To give even a synopsis of the results obtained under the above heads will not be possible here; those who desire to investigate seismic phenomena must consult the volumes themselves.

We see that Mr. Mallet was fully justified in demanding more thoroughly scientific observations than those we had previously to his work, and that he has given a most excellent example of how such investigations should be made. He has shown that we can not only learn much from the application of seismological inquiries to future earthquake shocks, but that we have it in our power, to a certain degree, to recover the history of the past, by investigating the results of former convulsions as registered in the buildings fissured or in the ruins of those overthrown by ancient earthquakes.

Among the practical results of investigations like those of Mr. Mallet, there are none so interesting to the public at large, especially to persons living in earthquake regions, as those which relate to the proper methods of structure for safe houses and other edifices in countries liable to these disturbances.

This experienced observer expresses his strong conviction, "that the evils of the earthquake, like all others incident to man's estate, may be diminished, or even multiplied, by the exercise of his informed faculties and energies, and by his application of forethought and knowledge to subjugate this, as every other apparent evil of his estate, by skill and labor." He further adds, in reference to this important question: '"Were understanding and skill applied to the future construction of houses and cities in Southern Italy, few, if any, human lives need ever again be lost by earthquakes, which there must recur, in their times and seasons."

What is true of Southern Italy should also be true of the Pacific coast of our own territory, a region liable to severe shocks, and yet where we hope to see populous States develop themselves in wealth, intelligence, and security to life. The prevailing tone in that region, at present, is that of assumed indifference to the dangers of earthquake calamities, — the author of a voluminous work on California, recently published in San Francisco, even going so far as to speak of earthquakes as "harmless disturbances." But earthquakes are not to be "bluffed off." They will come, and will do a great deal of damage. The question is, How far can science mitigate the attendant evils, and thus do something towards giving that feeling of security which is necessary for the full development of that part of the country?

There has repeatedly been talk at San Francisco of establishing an astronomical observatory, either by itself or in connection with the State university. If the people of California are wise, and have money to give for scientific research, let them found a physical, and not an astronomical, observatory. We have enough of the latter already, ill-equipped, and in the majority of cases not manned at all. Quite a sufficient number of large telescopes are rusting on their piers in various parts of the country, as valueless for all real scientific results as if they never had been taken from the boxes in which they were imported. Let California take warning from these, and remember that a very large endowment is necessary for the permanent maintenance of an astronomical observatory, and that, if not permanently maintained, in the hands of an able astronomer, with the means of paying his assistants and of publishing his results, it will be nothing but an expensive toy. Besides, the climate of California and the climatological conditions are ill-suited to astronomical work in a fixed observatory. The fogs of San Francisco, and the dust of the interior, will be found alike unfavorable to the successful prosecution of this branch of scientific research. A physical observatory, on the contrary, which need not necessarily be a permanency, having as its principal object the investigation of the seismological phenomena occurring on the Pacific coast, would, if properly managed, furnish results of exceeding value, not only

as contributions to an important branch of science hitherto much neglected, but as having a practical bearing on the welfare of the people and the development of the State, the value of which can hardly be overestimated. In no portion of the world is there a better chance for an establishment having in view the thorough investigation of earthquake phenomena. The great plain of the Sacramento and the San Joaquin should for a time be connected with San Francisco galvanically, by wires proceeding from the branch observatories at properly selected localities. Seismometers of the most approved construction should be set up, and their records compared with the other results of every important shock, as shown in the effect on buildings and on the surface of the ground, and in all the other methods of which Mr. Mallet's book furnishes so excellent a model.

Of Herr Volger's volume and theory something may be said at another time, in discussing the various theories of the nature of the forces involved in the phenomena of volcanoes and earthquakes.

J. D. WHITNEY.

ART. VIII. — THE SESSION.

THERE is much reason to regret that every voter in the United States cannot be compelled, at some period of his life, to visit Washington, for the purpose of obtaining the passage, through the various stages of legislation, of some little bill, interesting only to himself, and perhaps having "a little money in it." The lesson would be a useful one. As the visitor cast from the lobby a momentary glance through the swinging doors of the House, and was bewildered by the crash and war of jealous and hostile interests within, — as he felt how his own just and proper request was the sport of a thousand accidents, — as he appreciated the difficulties in the way of getting a committee to report his bill at all, and the still greater difficulty of putting it on its passage, and as he then watched it float here and there in the eddying current of legis-